A Brief Review on Landslide Hazard Zonation Models

International workshop on landslide risk assessment and management

for the asean member states

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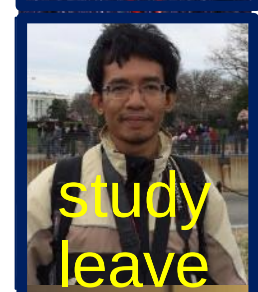
LSR Large Scale Simulation Research

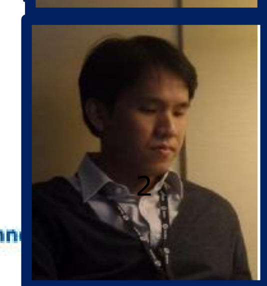
NECTEC a member of NSTDA

Missions

- Research/development on model-based prediction technology
  - Advanced numerical techniques, data processing and modeling
  - Large-scale optimization, inverse problems and data assimilation
  - Cloud computing and HPC in processing model-based prediction

- Transfer knowledge in prediction technology to private & public sectors
  - Near real-time / Non real-time applications
- Develop long-term competence in prediction technology
  - Advanced prediction technology and data analytics
  - Advanced data stream and complex event processing and analysis
  - Strategic alliances and partnerships

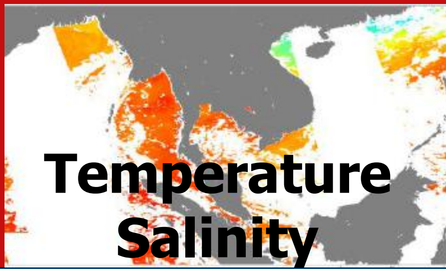




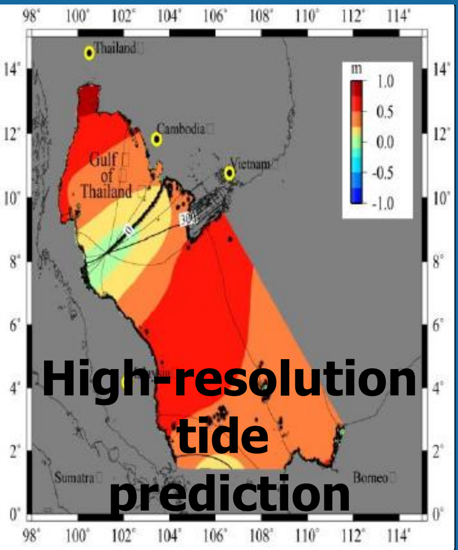
Estuarine and Coastal Modeling

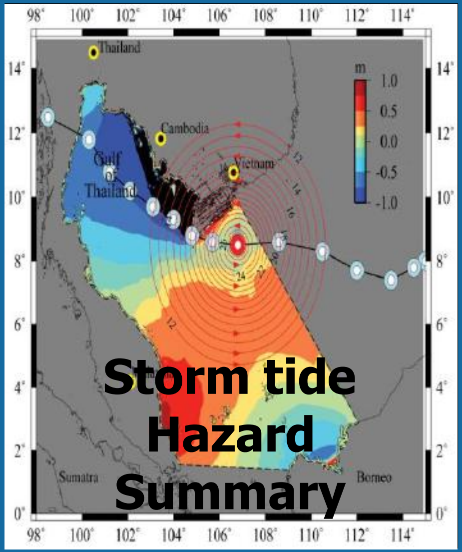
Done

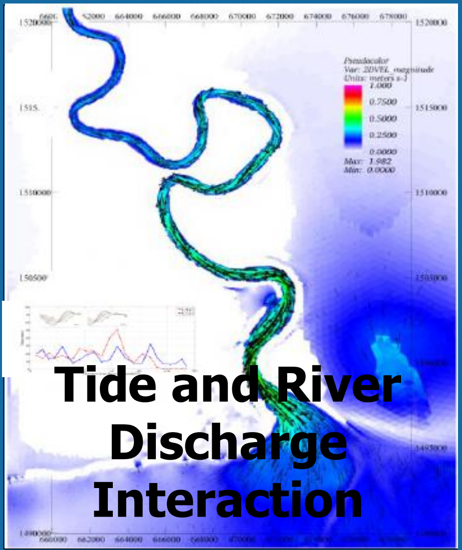
On going



Ocean Models ⟷ **Data Assimilation** ⟵ **Observations**



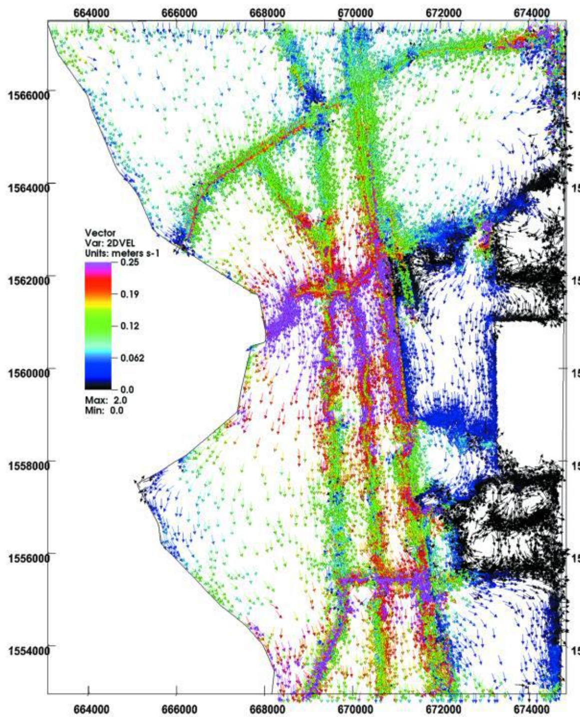


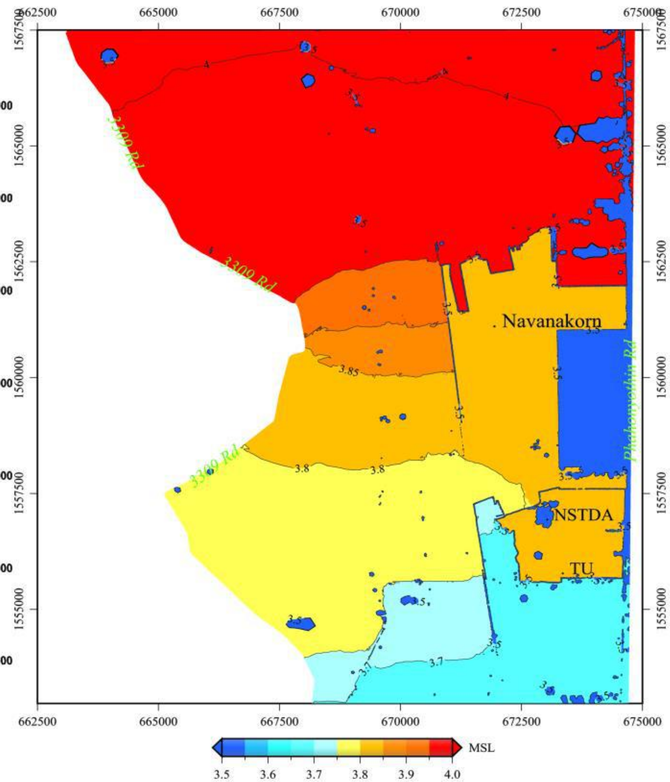


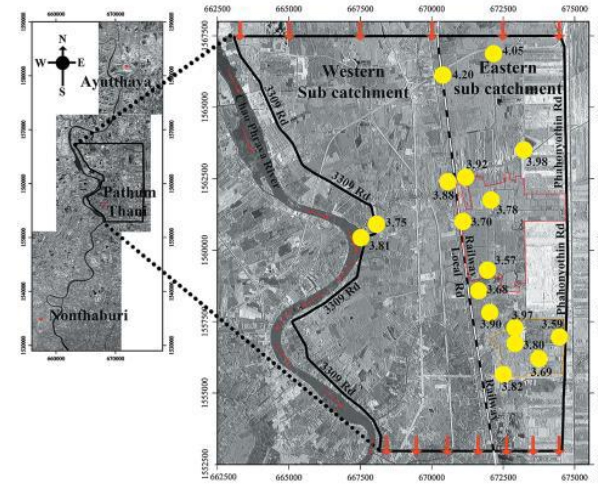
Potential applications

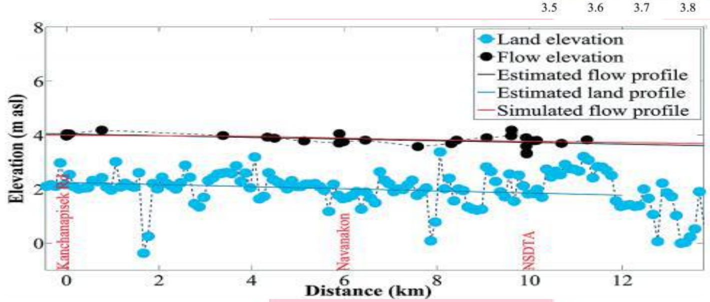
- Fishery and Ecology
- Pollution monitoring and management
- Disaster mitigation and rescue response
- Tourism and recreation

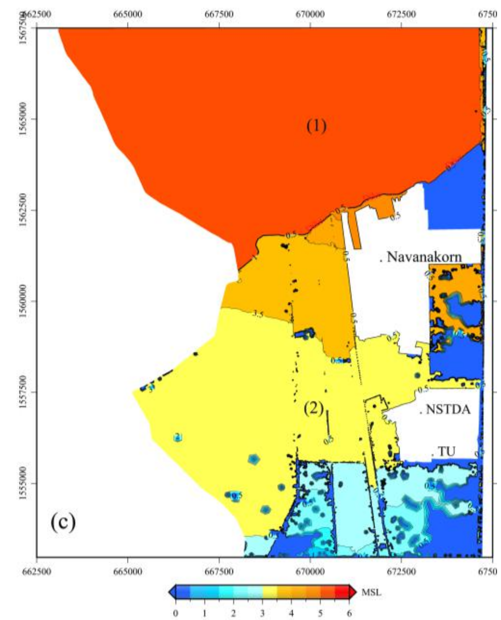
Overland flooding over low-lying flat lands











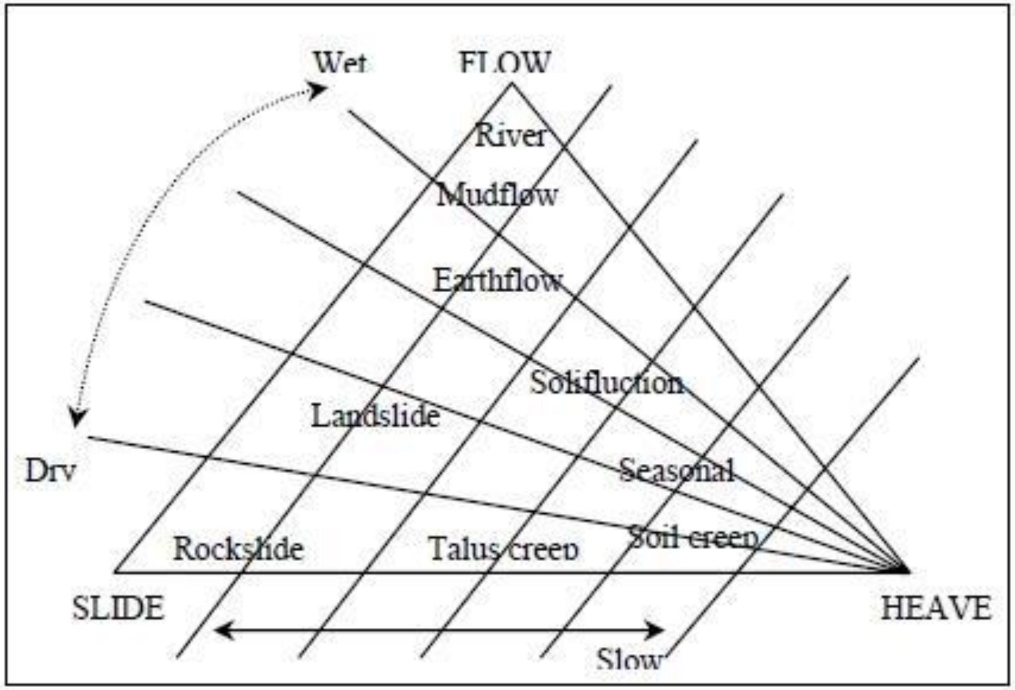
Hydrodynamic simulation of overland flooding over low-lying flat lands: A case study of the severe 2011 flood in Sam-Khok and Klong Luang districts, Thailand, **HRL**, 2015

Simulation of Estuarine Hydrological Characteristic: A Case Study of the Lower Chao Praya River , R&D journal of EIT, 2014

A Driving Force for National Science and Technology Capability

Landslides

Landslides are defined as the movement of rock, debris or earth down a slope (Cruden, 1991)



Triangle System Classification, Carson and Kirby 1972

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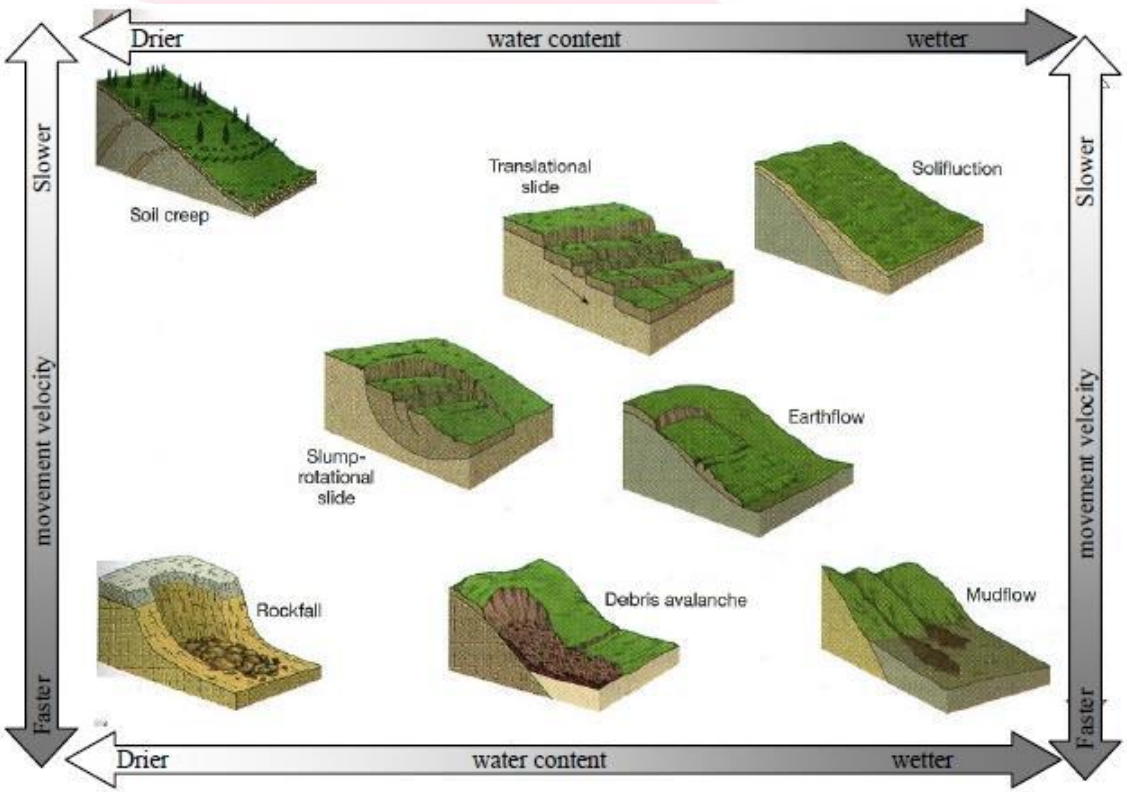

Field-view Classification, Carson and Kirby 1972

Landslide hazard zonation

"The process of division of land surface into areas and ranking of these areas according to the degree of actual or potential hazard from landslides or other mass movements" Varnes and IAEG (1984)

Important for landslide investigation and landslide risk management.

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Landslide data inventory

No	Data Type	Method and Sources of Data	Tools
1	Geomorphology		
	a. Geomorphology units	Geomorphology map, Image interpretation Aerial Photograph and field check	ILWIS, Arc GIS
	b. Landslide data	PGIS, Field investigation and field measurement	DGPS, Ancillary data
2	Topography		
	a. Digital Elevation Model (DEM)	Generate from TOPO Map, Aerial Photograph and DGPS Measurement	DGPS, ILWIS
	b. Slope Map	Generate from DEM	ILWIS
	c. Slope direction map	Generate from DEM	ILWIS
3	Engineering Geology		
	a. Lithology	From geological map and field check	Geological Map
	b. Structure	From geological map and field check	Geological Map, Geological Survey
4	Land use		
	a. Land use map	PGIS, field check and field description	Arc GIS, ILWIS
	b. Damage information	Administration map (village), field check, interview and field description	Questionnaire,
5	Soil		
	a. Soil Properties	Field investigation	Soil Test Kit, Munsel Color Chart, ITC Ganfeld
	b. Soil moisture	Field investigation	Soil Test Kit
	c. Soil thickness	Field investigation	Laser Ace, Tape Measurement, DGPS
	d. Stochastic parameters (bulk density, friction angle, cohesion)	Field and laboratory investigation	Soil Sampler (for undisturbed soil sample)
6	Hydrology		
	a. Drainage	Generate from DEM using LDD-PC raster	PC-Raster
	b. Catchments area	Topographic map or modeling from DEM	ILWIS
	c. Meteorological stations	Collection of existing meteorology data	Rain Gauge
	d. Water table	Field measurement of K-sat and modeling	Hydrological Model

Example of landslide data inventory

Morrocco S, Landslide Susceptibility Mapping Initial Review and Findings, 2011

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Landslide hazard zonation

Methods for Landslide hazard zonation (LHZ)

- Heuristic approaches
- Multi-criteria decision making
- Statistical approaches
- Probabilistic approaches
- and physically-based models

Heuristic approaches for LHZ

The heuristic approach is a knowledge base entails a substantial degree of subjectivity in as much as each geoenvironmental variable is assigned a certain amount of importance a priori. is a very simple and cost effective method.

Usually involve six landslide causative factors: lithology, structure, slope morphometry, relative relief, land use-land cover and hydrological condition.

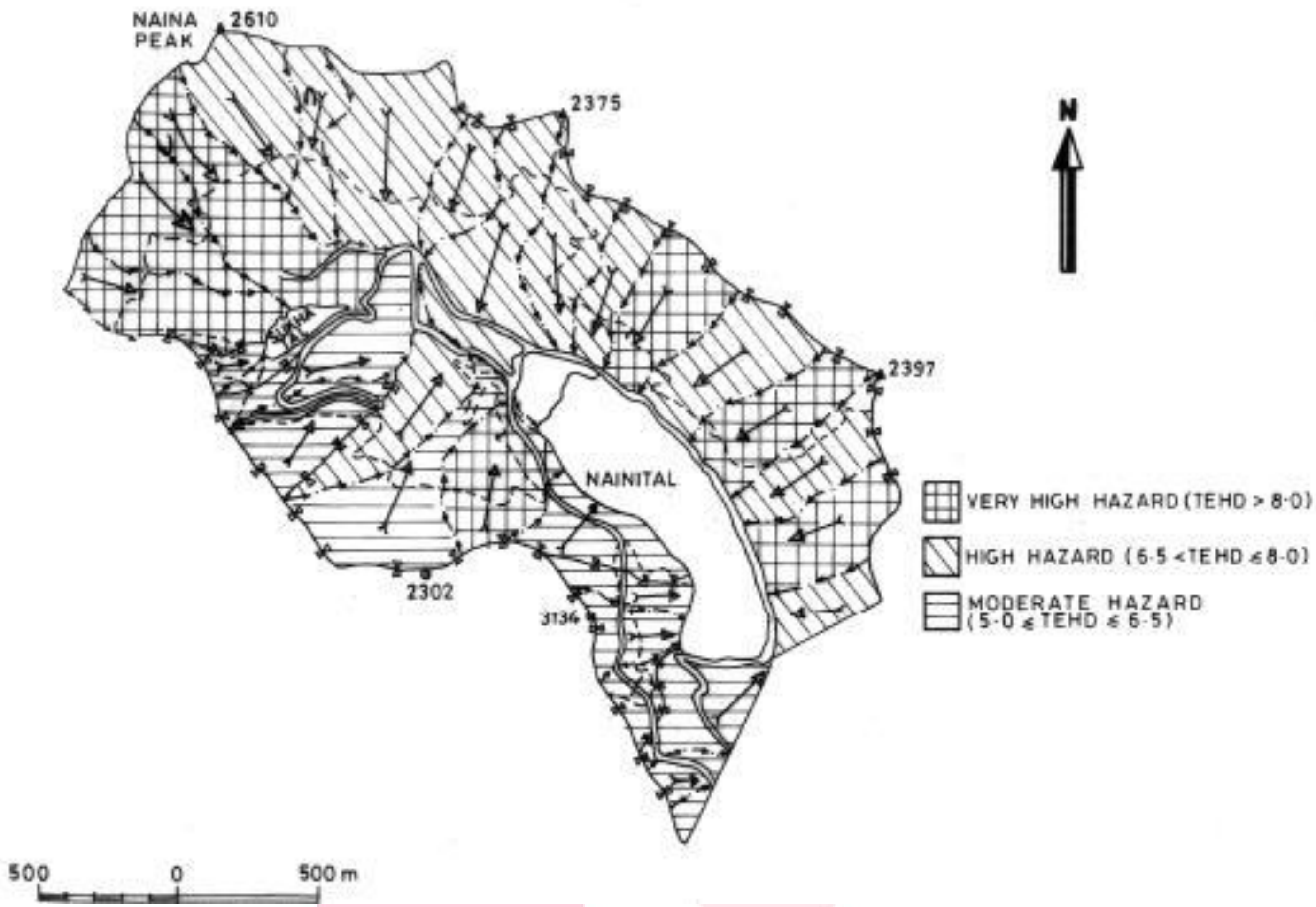
Examples:

Anbalagan et al. (2008) for Nainital, Kumaun Himalayas

Champatiray et al. 2007 and Kannan et al. 2011 for India

Ruff et.al (2008) for Eastern Alps Vorarlberg, Austria

Heuristic approaches for LHZ



LHZ for Nainital, Kumaun Himalayas.

R Anbalagan, D et. Al. J. Sci. Ind Res., Vol. 67, July 2008, pp. 486-497.

Multi-criteria decision making approach for LHZ

MCDA approach involves consideration of several landslide explanatory variables to determine relative contribution of an individual parameter in landslide occurrence.

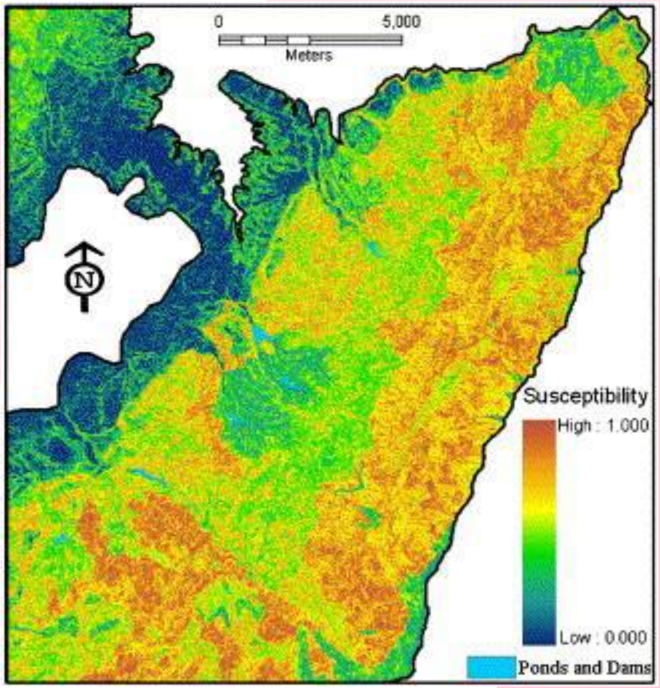
There are four levels in MCDA defining problem, determination of goals and alternatives, construction of pair wise comparison matrix, determining weights and obtaining overall priority.

Examples:

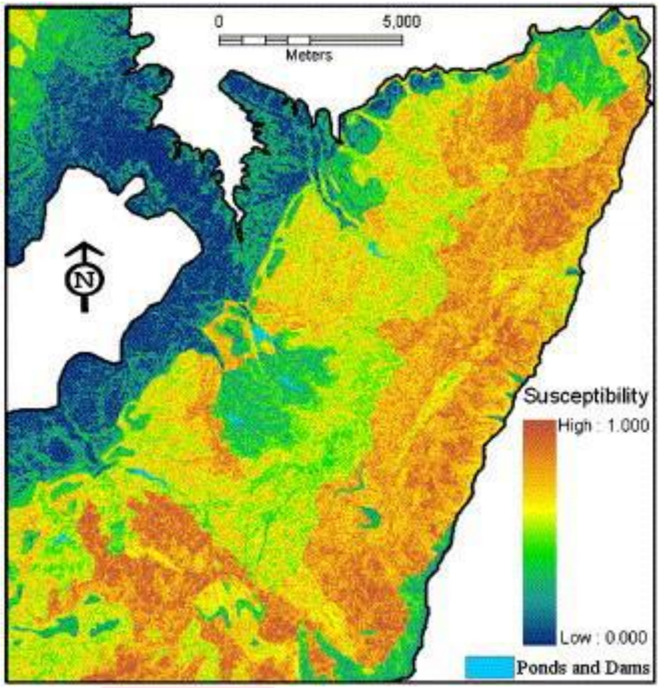
Ayalew et al. (2005) compared LHZ maps using LR and AHP model

Akgun (2011) compared LHZ maps using Logistic Regression (LR), Multi Criteria Decision Approach (MCDA) and Likelihood Ratio Method (LRM)

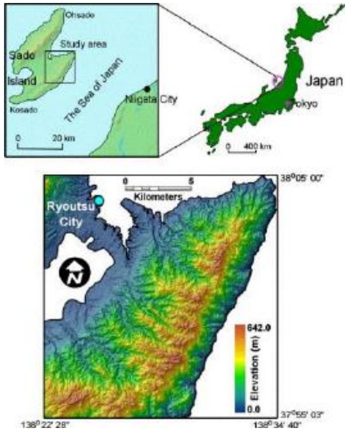
Multi-criteria decision making approach for LHZ



LR



MCDA



L. Ayalew et al. / Engineering Geology 81 (2005) 432–445

Statistical approaches for LHZ

The statistical approach is data-driven approach to overcome the subjectivity in weight assignment procedure and can produce more objective results.

The statistical methods are categorized into two groups

Bi-variate statistical analysis

Multi-variate statistical analysis.

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Statistical approaches for LHZ

Bi-variate statistical analysis compares each data layer of causative factors to the existing landslide data. Weights to the landslide causative factors are assigned differently in each model.

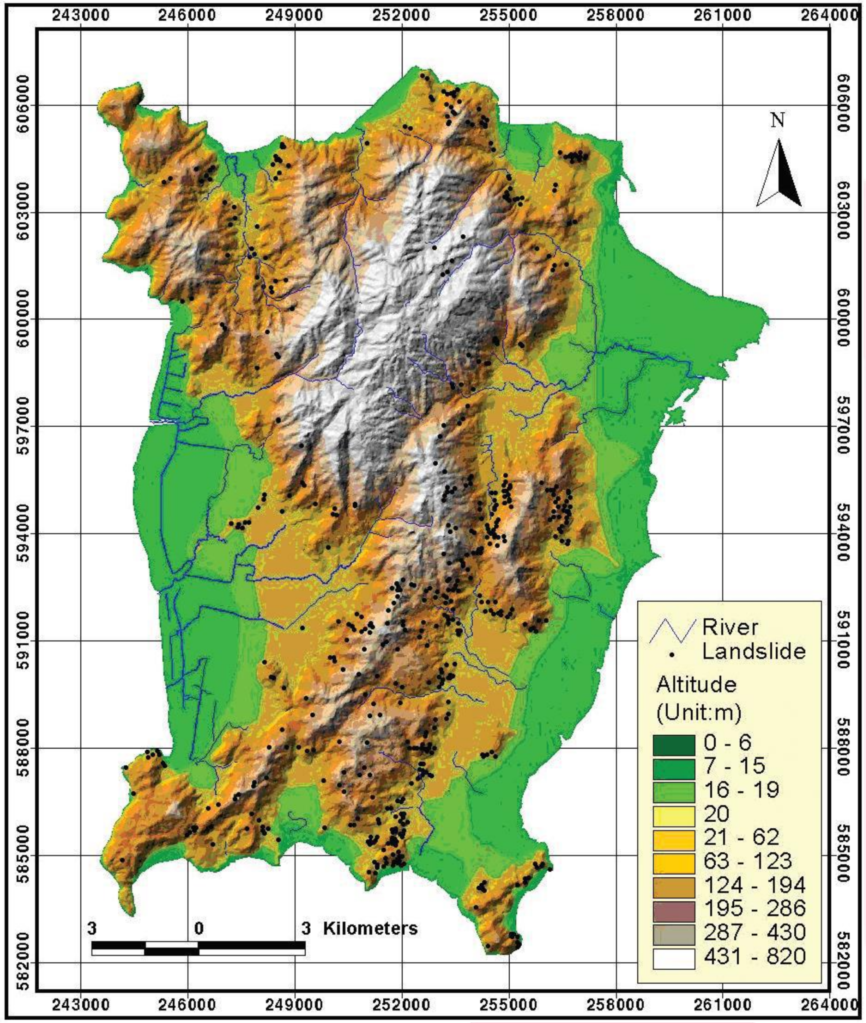
Bi-variate statistical analysis includes Frequency Analysis approach (distribution), Information Value Model (IVM)(aux parameters), Weights of Evidence Model (+/-, occurrences), Weighted overlay model (frequency), Fuzzy logic Model (0/1, occurrences)

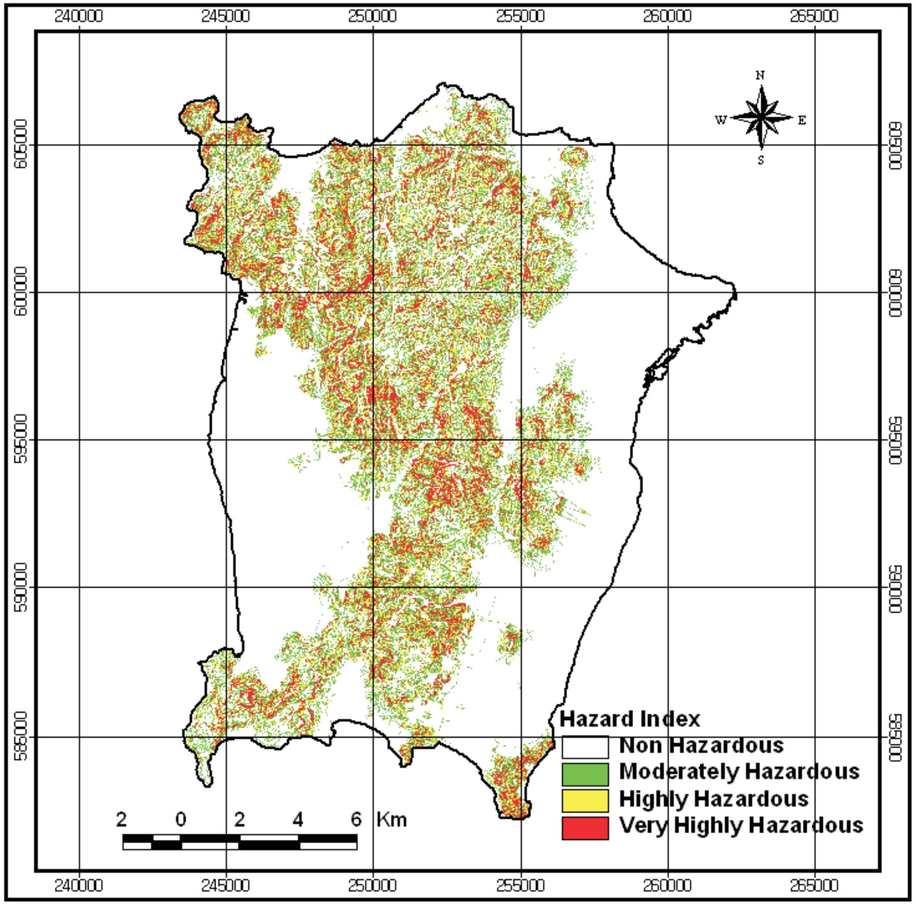
Examples:

Lee S, Pradhan B (2006) for Penang Malaysia with FA

Arora M et. al. (2004) for Bhagirathi (Ganga) Valley, Himalaya with IVM

Statistical approaches for LHZ





Lee S, Pradhan B (2006) J Earth Syst Sci 115:661–672

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Statistical approaches for LHZ

Multi-variate statistical analysis accounts interrelationships among the causative factors also determine the degree of landslide hazard.

Multi-variate statistical analysis includes Logistic regression model, Discriminant analysis, Multiple regression models, Conditional analysis, Artificial Neural Networks (ANN)

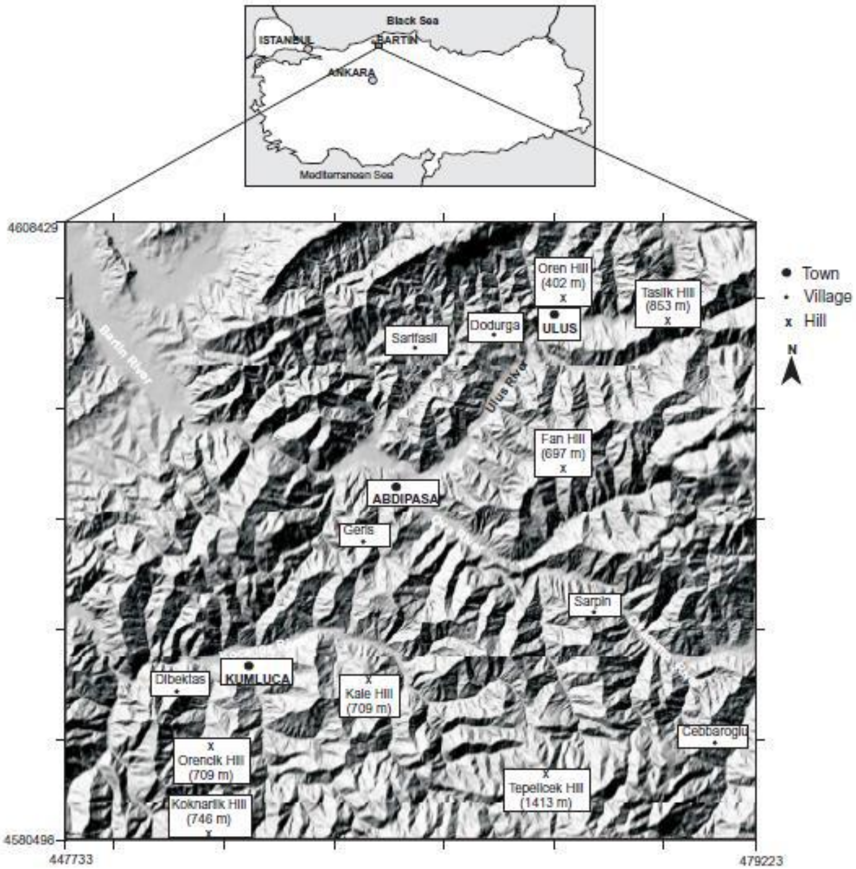
Examples:

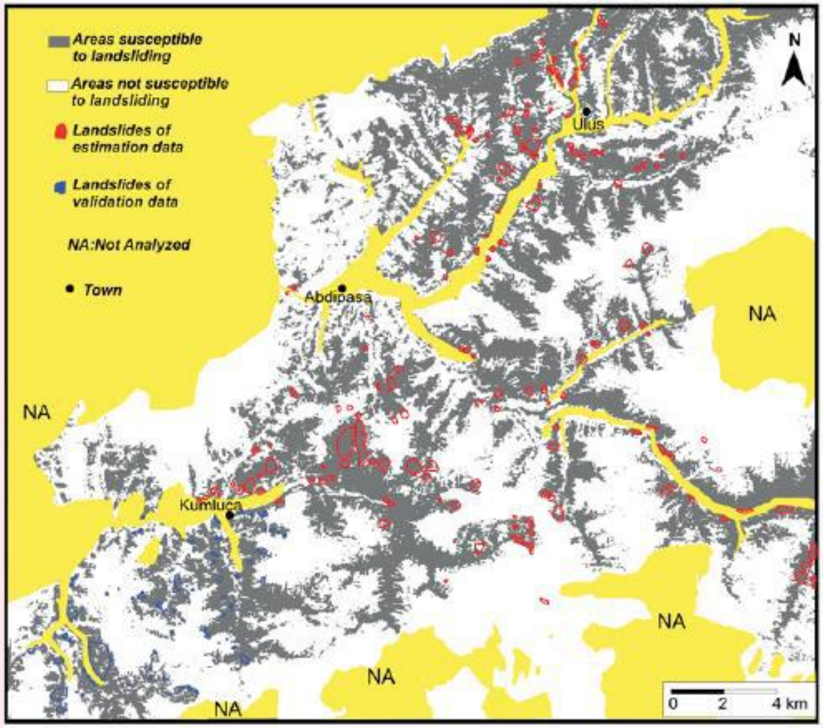
Rowbotham and Dudycha (1998) for Hong Kong. LR

Ercanglu (2005) for west Black Sea, Turkey. ANN

Lee et al. (2008) for central westernTaiwan. DA

Statistical approaches for LHZ





Ercanglu M (2005) Nat Hazard Earth Syst Sci 5:979–992

Probabilistic approaches for LHZ

The probabilistic approach helps to determine spatial, temporal and size probability of landslides. Spatial distribution of landslides is compared with various explanatory variables within probabilistic framework.

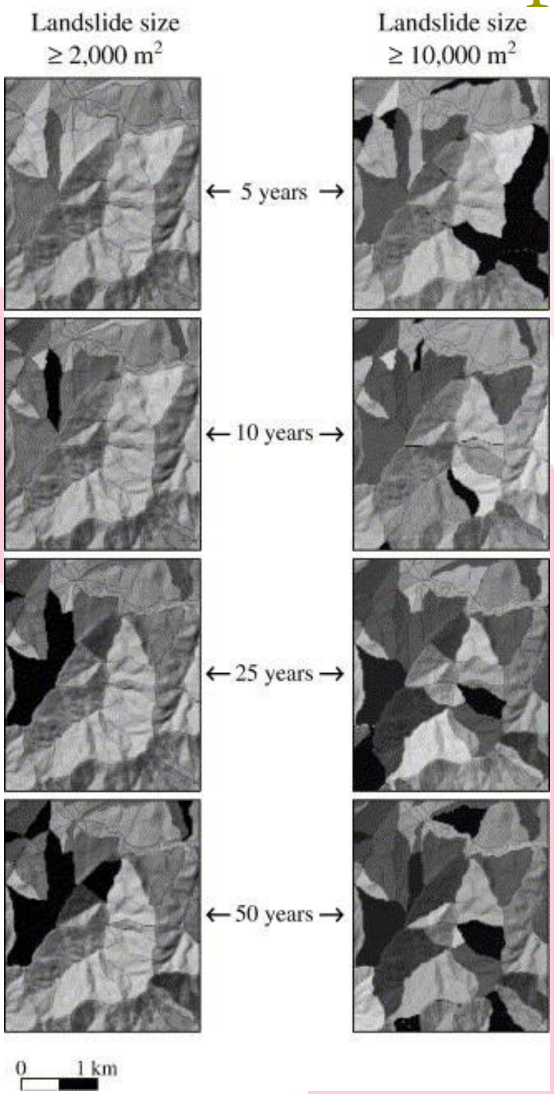
The approach includes Bayesian probability, certainty factor, favorability function etc. The degree of relationship between each thematic data layer with landslide distribution is transformed to a value based on PDF.

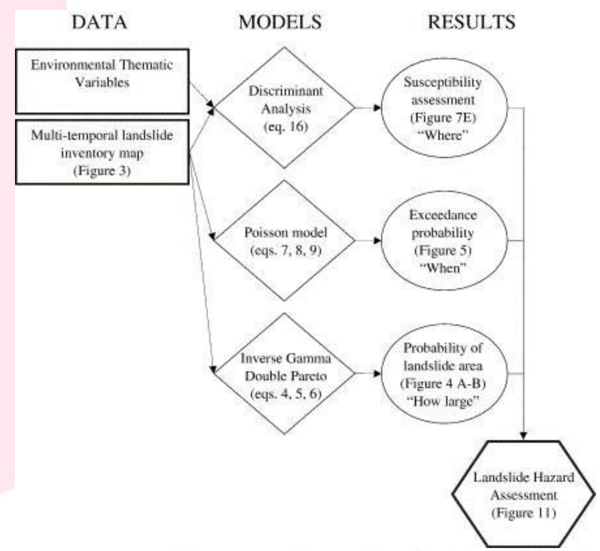
Examples:

Guzzetti et al. (2005) for Staffora River basin of north Apennines, Italy

Jaiswal et al. (2010) for Nilgiri Hills, India.

Probabilistic approaches for LHZ





Guzzetti et al, Geomorphology (72), Issues 1–4, 2005, pp. 272–299

Physically-based models for LHZ

Physically based models for LHZ describes physical processes leading to the landslide event and are based on mechanical laws.

- Transient ground water response of slope to rainfall
- Do not need long term landslide data and applicable to the areas with incomplete landslide inventories

Examples:

Transient Rainfall Infiltration and Grid based Slope Stability (TRIGRS), Salciarini et al. (2006)

SLIP (shallow Landslide Instability Prediction) and TRIGRS, Montrasio et al. (2011)

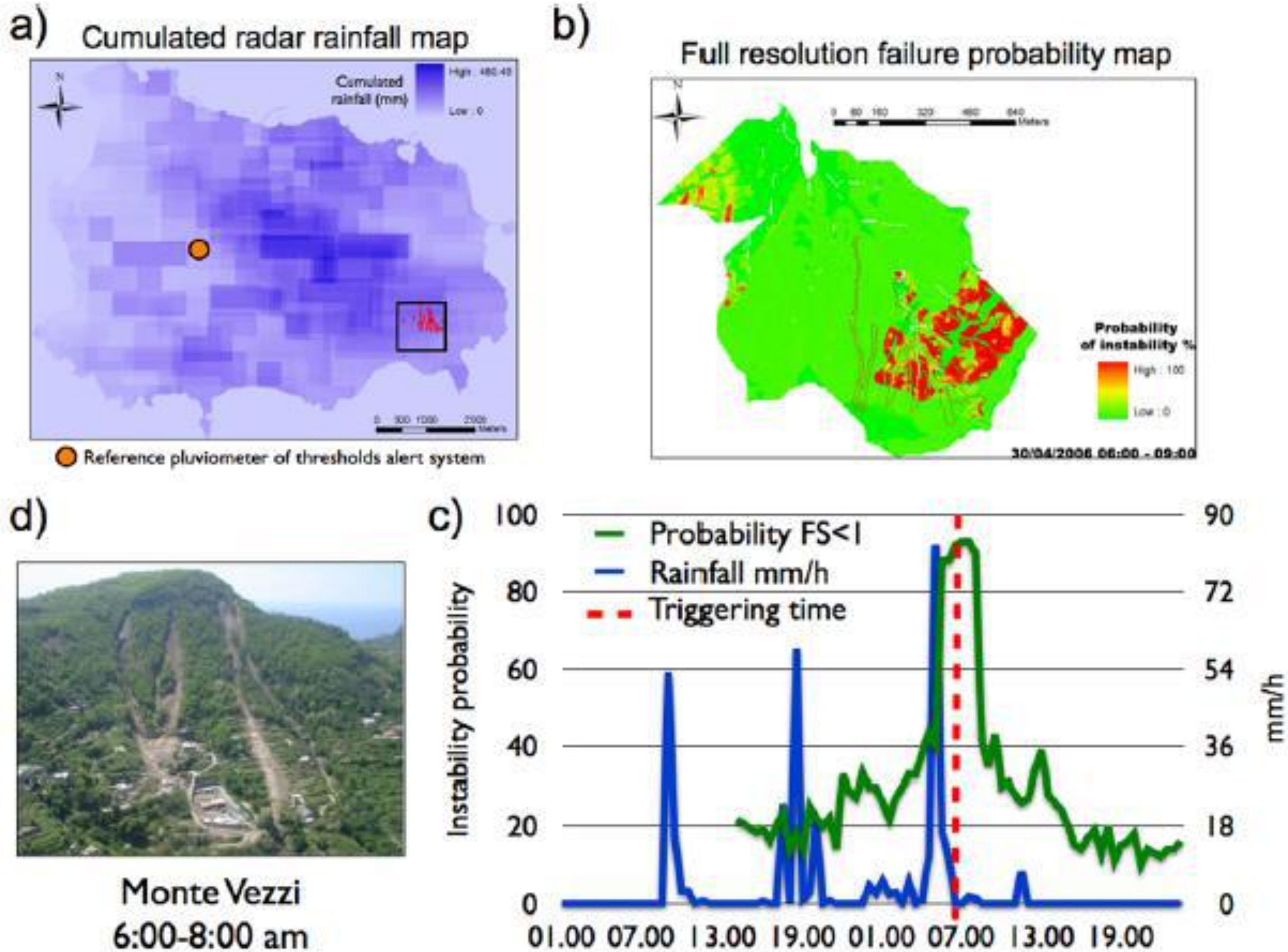
SHALSTAB (Shallow Landsliding Stability), SINMAP (Stability Index MAPping), TRIGRIS and STARWAR+PROBSTAB (Storage and Redistribution of Water on Agricultural andRevegetated Slope + PROBability of STABility), Kuriakose (2010)

High Resolution Slope Stability Simulator (HIRESSS), Mercogliano et al. (2013).

Physically-based models for LHZ

HIRESS Includes

Hydrological models and
Geotechnical model



Mercogliano,Nat. Hazards Earth Syst. Sci., 13, 151–166, 2013

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10. Fommetta G. (2016), Hydrol. Earth Syst. Sci., 20, 4585–4603, 2016

Thank You !